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SHOULD INDIA INVEST MORE IN LESS-FAVORED AREAS?

Shenggen Fan and Peter Hazell

Environment and Production Technology Division

International Food Policy Research Institute
1200 Seventeenth Street, N.W.
Washington, D.C. 20036-3006 U.S.A.

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ABSTRACT

Developing countries have to allocate limited government resources for rural areas among different investment activities and regions to achieve the twin goals of productivity growth and poverty alleviation. This is particularly important at a time when many countries are facing severe financial constraints. This paper develops a framework and provides empirical evidence on the impact of government investments in technology, irrigation, education and infrastructure on agricultural productivity growth and rural poverty reduction in rural India. The results reveal that government investments in more favored areas played significant roles during the green revolution period. But the marginal returns from additional government investments in these areas have declined in more recent years. It is now the less-favored areas where marginal returns are higher. This result has important policy implications for where government investments should be targeted in order to achieve further productivity growth and rural poverty reductions.

CONTENTS

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1. INTRODUCTION

Since independence, India has invested heavily in rural areas in generating new technologies (research and extension), and in improving rural infrastructure (roads, irrigation and electricity), education and health. Understanding how these investments have contributed to growth in agricultural productivity and to reductions in rural poverty is particularly important at a time when the government is undertaking a series of major policy reforms. Amongst other things, these reforms seek a more efficient allocation of public investments. Questions that arise are: (a) What is the optimal level of public investment in agriculture? and (b) How should public investments be allocated among different types of investments and among regions in order to achieve the twin goals of productivity growth and further reductions in rural poverty?

In the past, government investments have been biased towards irrigated areas. About

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52 percent of total government investments in 1987 were devoted to irrigated areas that cover only less than 30 percent of the Indian geographic areas[1]. But as the marginal returns in these areas have declined over time, policymakers are increasingly looking to rainfed areas for future agricultural growth. Rainfed agriculture accounts for more than 70 percent of India's geographic areas and 42 percent of total agricultural production, and will need to play a key role in meeting India's future food needs, in generating employment, in promoting further national economic growth, and in reducing rural poverty. Rainfed areas are diverse, ranging from resource-rich areas with high agricultural potential to resource-poor areas with relatively low potential. Some of the rainfed areas have already experienced widespread adoption of high-yielding varieties and other new technologies, and consequently enjoy higher production and productivity growth. In other areas, production and productivity growth have lagged behind, and there is widespread poverty.

This paper uses district level data for 1956 to 1990 to examine the relationships among technologies and infrastructure, productivity growth, and poverty reduction in both rainfed and irrigated areas. We further disaggregate rainfed areas into high- and low-potential regions in order to analyze any differences in the impacts of public investments on productivity growth and poverty alleviation. We attempt to answer the following questions: What have been the determinants of productivity growth and poverty reduction in rural India? Do improved technologies and infrastructure in rainfed areas have smaller effects on productivity growth and poverty reduction than irrigated areas? Similarly, within rainfed areas, do improved technologies and infrastructure in low-potential areas have smaller

[1] Calculated from state level data provided by V. Misa. We classify a state as irrigated if more than 30 percent of the cropped areas are irrigated, and as a rainfed areas otherwise.

impacts on productivity growth and poverty reduction than high-potential areas? Is there any tradeoff between productivity growth and poverty reduction in the returns to public investments in technologies and infrastructure in different types of regions?

The paper is organized as follows. In the next section, we briefly overview the characteristics of the major agroecological zones in Indian agriculture and present our definition of rainfed and irrigated areas, and low- and high-potential areas. In the third section, we review the historical development of technologies and infrastructure in recent decades in rural India. The third section analyzes production and productivity growth and their regional differences. The fourth section describes changes in rural poverty between 1972 and 1987 and differences among agroecological zones and regions. The fifth section develops econometric models to analyze the effects of improved technologies and infrastructure on both productivity growth and poverty reduction in Indian agriculture and presents the results. We conclude the paper with a discussion of some of the implications for future public investment priorities.

2. CLASSIFICATIONS OF INDIAN AGROECOLOGICAL ZONES

Following Kerr (1996), we classify districts as irrigated if more than 25 percent of the cropped area (averaged from 1956 to 1990) is irrigated, and as rainfed if the irrigated share is less than 25 percent.

We further subdivide rainfed areas into high- and low-potential areas according to their agroecological characteristics. There have been several attempts to define agroecological zones in India. In this study we adopted the classification scheme of the Indian Council of

Agricultural Research (ICAR), which divides India into 20 agroecological zones based on soils and climate (NBSS&LUP, 1992). The district data available to us cover twelve of these zones. Of the rest, six zones are in the Northeast, the Himalayas, and the Andaman, Nicobar and Lakshadweep Islands; one zone covers the high rainfall areas of the Western Ghats and the Arabian Sea coast; and one zone covers the desert in the western parts of Rajasthan and Gujarat. Table 1 presents some distinguishing features of each zone. Zones 2 to 8 are considered low-potential areas in this study mainly because of their poor soils, short growing periods, and low rainfall. The rest of the country (zones 9, 10, 11, 12, 13, and 18) is considered high potential because these zones have better soils, longer growing periods, and higher rainfall.

3. TECHNOLOGIES AND INFRASTRUCTURE

One of the most significant changes in Indian agriculture in the past several decades has been the widespread adoption of high-yielding varieties. During the green revolution period (1967-76), the crop area planted to high-yielding varieties (HYVs) for five major crops (rice, wheat, maize, sorghum, and pearl millet) increased from less than 5 percent to 37 percent (table 2)[2]. Even after the green revolution, the percentage of the crop area planted with

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[2] High-yielding varieties (also referred to as modern varieties) are those released by the Indian national agricultural research system and the international agricultural research centers. The yields of these varieties are usually substantially higher than those of traditional varieties.

Table 1 ICAR s 20 agroclimatic zones

1*	Western Himalayas, cold arid ecoregion, with shallow skeletal soils and length of growing period (GP) less than 90 days
2[1]	Western plain, Kachch and part of Kathiawar peninsula, hot arid ecoregion, with desert and saline soils and GP < 90 days
3[1]	Deccan Plateau, hot arid ecoregion, with red and black soils and GP < 90 days
4[1]	Northern plain and central highlands including Aravalli hills, hot semi-arid ecoregion, with alluvium derived soils and GP 90-150 days.
5[1]	Central (Malwa) highlands, Gujarat plains and Kathiawar peninsula, hot semi-arid ecoregion, with medium and deep black soils and GP 90-150 days
6[1]	Deccan Plateau, hot semi-arid ecoregion, with mainly shallow and medium but also some deep black soils and GP 90-150 days.
7[1]	Deccan Plateau of Telengana and Eastern Ghats, hot semi-arid ecoregion with red and black soils and GP 90-150 days.
8[1]	Eastern Ghats, Tamil Nadu uplands and Deccan Plateau of southern Karnataka, hot semi-arid ecoregion with red loamy soils and GP 90-150 days.
9	Northern plain, hot subhumid (dry) ecoregion, with alluvium-derived soils and GP 150-180 days.
10	Central highlands (Malwa, Bundelkhand and Eastern Satpura), hot subhumid ecoregion, with black and red soils and GP 150-180 days (up to 210 days in some places).
11	Eastern plateau (Chhatisgarh), hot subhumid ecoregion, with red and yellow soils and GP 150-180 days.
12	Eastern (Chhotanagpur) plateau and Eastern Ghats, hot subhumid ecoregion with red and lateritic soils, and GP 150-180 days (up to 210 days in some places).
13	Eastern Gangetic plain, hot subhumid (moist) ecoregion, with alluvium-derived soils and GP 180-210 days.
14*	Western Himalayas, warm subhumid (to humid and perhumid) ecoregion, with alluvium-derived soils and GP 210+ days.
15**	Bengal and Assam Gangetic and Brahmaputra plains, hot subhumid (moist) to humid (and perhumid) ecoregion, with alluvium-derived soils and GP 210+ days.
16*	Eastern Himalayas, warm perhumid ecoregion with brown and red hill soils and GP 210+ days
17*	Northeastern hills (Purva chal), warm perhumid ecoregion with red and lateritic soils and GP 210+ days.
18	Eastern coastal plain, hot subhumid to semi-arid ecoregion, with coastal alluvium-derived soils and GP 90-210+ days.
19*	Western ghats and coastal plain, hot humid-perhumid ecoregion with red, lateritic and alluvium-derived soils, and GP 210+ days.
20*	Islands of Andaman-Nicobar and Lakshadweep hot humid to perhumid island ecoregion, with red loamy and sandy soils, and GP 210+ days.

* Indicates zones not included in the district level data., and superscript [1] indicates low potential areas.
** District level data contains Zone 13 districts in West Bengal but not Assam.

Source: NBSS&LUP, 1992

Table 2 Trends in technology and rural infrastructure in rural India: Rainfed vs irrigated areas

Year	Adoption of High-Yielding Varieties			Road Density			Literacy Rate			Irrigation		
	Rainfed	Irrigated	All India	Rainfed	Irrigated	All India	Rainfed	Irrigated	All India	Rainfed	Irrigated	All India
	(percent)			km/km2			(percent)			(percent)		
1956	0.0	0.0	0.0	1186	1294	1232	23.2	23.6	23.8	7.0	33.1	18.1
1957	0.0	0.0	0.0	1216	1330	1265	24.0	24.3	24.6	7.3	34.6	19.0
1958	0.0	0.0	0.0	1242	1340	1284	24.7	25.0	25.5	6.8	33.3	18.2
1959	0.0	0.0	0.0	1277	1379	1320	25.4	25.8	26.3	7.0	33.5	18.3
1960	0.0	0.0	0.0	1314	1403	1352	26.1	26.5	27.0	7.2	34.3	18.8
1961	0.0	0.0	0.0	1334	1405	1365	26.8	27.1	27.9	7.0	30.5	17.1
1962	0.0	0.0	0.0	1371	1450	1405	27.3	27.8	28.6	7.1	31.0	17.4
1963	0.0	0.0	0.0	1401	1495	1441	27.7	28.3	29.2	7.4	34.6	19.0
1964	0.0	0.0	0.0	1483	1517	1498	28.2	28.9	29.9	7.8	34.7	19.4
1965	0.0	0.0	0.0	1560	1573	1565	28.7	29.4	30.4	8.0	37.0	20.5
1966	1.1	1.6	1.3	1640	1644	1642	29.3	30.0	31.0	8.4	38.4	21.3
1967	3.5	5.9	4.6	1735	1665	1705	29.7	30.4	31.6	8.7	36.7	20.8
1968	6.2	9.6	7.6	1765	1707	1741	30.1	31.1	32.1	8.9	39.9	22.1
1969	6.8	13.3	9.6	1803	1726	1770	30.5	31.6	32.6	9.1	40.6	22.6
1970	10.1	17.5	13.3	1877	1814	1850	30.9	31.9	33.1	9.6	41.6	23.4
1971	11.1	22.1	15.9	2033	1886	1969	31.4	32.6	33.1	10.0	41.6	23.7
1972	13.8	25.5	19.0	2143	1973	2068	32.1	33.4	33.8	9.8	42.7	24.3
1973	18.0	29.8	23.0	2290	2030	2178	32.9	34.2	34.5	10.1	42.6	24.0
1974	19.8	30.3	24.3	2347	1970	2185	33.6	34.8	35.2	10.6	44.3	25.1
1975	24.8	32.3	28.0	2415	2209	2327	34.3	35.7	35.9	11.7	44.3	25.7
1976	26.9	49.5	36.7	2627	2320	2494	35.0	36.4	36.5	12.1	46.4	27.0
1977	30.8	52.4	40.1	3134	2546	2880	35.7	37.4	37.2	12.5	47.4	27.6
1978	32.0	53.3	41.3	3143	2718	2957	36.3	37.9	37.9	13.1	47.8	28.3
1979	31.8	55.7	42.1	3372	2951	3191	37.1	38.9	38.6	13.2	52.0	29.9
1980	35.2	55.6	44.0	3507	2921	3253	37.8	39.5	39.3	13.6	50.9	29.8
1981	38.6	60.5	48.1	3774	3229	3538	39.1	41.9	42.1	13.5	49.5	29.1
1982	41.1	62.8	50.3	3947	3123	3598	39.7	42.1	42.8	15.1	54.2	31.7
1983	45.6	64.2	53.5	4203	3467	3889	40.5	43.1	43.6	15.4	53.2	31.5
1984	46.4	67.2	55.5	4140	3454	3842	41.4	44.0	44.3	16.3	55.4	33.3
1985	49.5	69.4	58.2	4108	3407	3803	42.1	44.8	45.1	16.2	54.7	33.0
1986	48.3	71.1	58.3	4148	3306	3780	42.8	45.7	45.8	17.0	55.9	34.0
1987	45.3	67.4	54.8	4242	3389	3874	43.4	46.4	46.6	17.2	57.6	34.7
1988	52.6	74.4	62.2	4422	3670	4093	44.1	48.1	47.5	18.4	55.1	34.5
1989	55.5	78.0	65.3	4831	3989	4466	45.0	49.2	48.4	18.4	56.3	34.8
1990	59.0	82.9	69.3	5061	4167	4674	45.8	50.3	49.4	18.6	55.7	34.6

Notes: Road density is measured as kilometers of roads per thousand square kilometers of cropped land.

HYVs continued to increase. In 1990, 70 percent of the crop area in Indian was planted with HYVs. This has been one of the major engines of production and productivity growth in Indian agriculture. However, there have been substantial regional differences. The irrigated areas have generally outperformed the rainfed areas in HYV adoption. During the green revolution period, the adoption rate of HYVs in irrigated areas increased from 6 percent to 50 percent, but from 3.5 percent to 27 percent in the rainfed areas. Since the green revolution, the adoption rate in irrigated areas has increased further to 83 percent. But in rainfed areas, more than 40 percent of the cropped area was still planted with traditional varieties in 1990.

Irrigation, another important factor in Indian agriculture, has also increased dramatically, but with considerable regional variation. For all India, the percentage of the cropped area that is irrigated increased from 18 percent in 1956 to 35 percent in 1990. In irrigated areas, more than 55 percent of the cropped area was irrigated in 1990, compared to 33 percent in 1956. Although it has grown rapidly, only 19 percent of the cropped area was irrigated in rainfed areas in 1990. Since HYVs respond well to irrigation and high rates of fertilizer, lack of irrigation facilities in rainfed areas has hindered more widespread adoption and effectiveness of HYVs.

Road density in rural India, measured as the length of roads in kilometers per thousand square kilometers of net cropped area, increased from 1,232 in 1956 to 4,674 in 1990; a growth rate of 4 percent a year. In contrast to the adoption of HYVs and increased irrigation, the road density in rainfed areas has exceeded that in irrigated areas since the 1970s.

There was no noticeable difference in the literacy rate of rural population between irrigated and rainfed areas in the 1950s and 1960s[3]. But in the past 20 years, literacy has improved more slowly in rainfed than irrigated areas. In 1990, the literacy rate in irrigated areas was four percentage points higher than that in rainfed areas.

4. PRODUCTION AND PRODUCTIVITY GROWTH

As a result of rapid adoption of new technologies and improved rural infrastructure, production and factor productivity have grown rapidly in India (table 3). Five major crops (rice, wheat, sorghum, pearl millet, and maize), and fourteen minor crops (barley, cotton, groundnut, other grain, other pulses, potato, rapeseed, mustard, sesame, sugar, tobacco, soybeans, jute, and sunflower) are included in total production[4]. Unlike traditional measures of production growth which use constant output prices, we use the more appropriate Tornqvist-Theil index (a discrete approximation to the Divisia index). As Richter (1966) has shown, the Divisia index is desirable because of its invariance property: if nothing real has changed (e.g., the only input quantity changes involve movements around an unchanged isoquant) then the index itself is unchanged (Alston, Pardey and Norton, 1995). The formula

[3] The literacy rate, obtained from the decennial population census, is the proportion of rural males who are classified as literate, which is defined as "the ability to read and write in any language". Data for the inter-censal years were obtained by linear interpolation.

[4] Ideally, livestock and fishery products should also be included in total output, but the outputs of these products are not available at the district level.

Table 3 Production and productivity growth in Indian agriculture (1956=100): Rainfed vs irrigated

Year	Production			Land Productivity			Labor Productivity			Total Factor Productivity		
	Rainfed	Irrigated	All India	Rainfed	Irrigated	All India	Rainfed	Irrigated	All India	Rainfed	Irrigated	All India
1956	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1957	83.27	89.30	86.52	85.50	91.33	88.69	82.47	89.53	86.25	84.37	90.56	87.73
1958	109.87	103.77	106.36	108.79	102.50	105.20	107.77	103.01	105.00	108.30	102.33	104.88
1959	102.29	106.98	104.71	100.69	105.34	103.09	99.38	105.81	102.72	100.03	104.76	102.47
1960	113.71	122.33	118.09	112.75	119.96	116.54	109.44	120.55	115.11	111.30	119.15	115.38
1961	121.09	131.45	126.39	117.75	126.19	122.22	115.47	129.08	122.43	116.41	125.58	121.22
1962	115.14	118.87	116.81	111.71	113.07	112.38	106.71	114.67	110.61	109.70	111.72	110.65
1963	120.40	116.73	118.00	115.69	111.35	113.03	108.53	110.67	109.27	113.04	108.98	110.50
1964	129.84	141.55	135.81	124.53	133.54	129.34	113.92	131.94	123.06	120.62	129.87	125.48
1965	97.88	122.03	110.80	96.14	117.80	108.03	83.65	111.84	98.27	92.02	113.52	103.72
1966	97.03	119.67	109.11	94.55	115.29	105.80	80.82	107.89	94.78	89.83	110.46	100.95
1967	128.89	154.28	142.23	122.49	143.09	133.76	104.72	136.85	121.05	115.96	136.46	127.04
1968	117.51	141.47	130.12	110.57	133.37	122.53	93.18	123.50	108.55	104.01	124.83	114.91
1969	129.44	163.42	147.35	119.31	148.23	134.88	100.23	140.43	120.53	111.94	138.34	126.04
1970	140.22	176.52	159.28	129.95	159.79	146.13	106.08	149.36	127.80	119.64	147.88	134.77
1971	137.68	174.42	157.02	128.53	157.70	144.58	110.90	143.15	127.76	118.47	144.27	132.57
1972	113.93	169.37	143.70	110.34	154.75	135.70	90.30	137.30	115.28	100.08	140.22	122.78
1973	147.15	171.12	159.72	133.51	153.36	144.15	114.79	137.04	126.36	122.38	139.18	131.34
1974	138.59	177.99	159.24	128.52	163.36	147.01	106.43	140.83	124.26	116.93	148.20	133.51
1975	165.60	203.21	185.22	149.85	183.05	167.28	125.24	158.89	142.60	137.48	164.49	151.67
1976	151.13	186.24	169.52	140.90	168.97	156.20	112.57	143.91	128.77	126.47	148.59	138.41
1977	174.65	212.53	194.31	156.65	187.01	172.86	128.16	162.33	145.68	140.52	163.06	152.44
1978	173.51	219.09	197.18	153.95	186.23	171.74	125.47	165.42	145.92	137.15	161.55	150.37
1979	146.24	176.51	161.99	132.80	157.52	146.01	104.23	131.77	118.35	116.62	132.17	124.83
1980	166.47	218.55	193.45	150.69	192.82	173.19	116.96	161.33	139.55	131.59	161.30	147.38
1981	180.74	225.85	204.13	160.76	196.13	179.71	125.21	164.88	145.42	138.85	162.42	151.34
1982	171.26	225.30	199.37	152.11	201.99	177.79	116.49	162.29	139.81	130.38	160.61	146.12
1983	207.33	255.80	232.22	177.27	218.57	198.50	138.49	181.84	160.35	150.87	174.21	162.77
1984	209.83	264.09	237.82	194.07	236.64	216.98	137.71	185.31	161.73	159.06	183.18	171.84
1985	214.68	286.37	252.00	200.45	257.49	231.50	138.46	198.37	168.81	161.90	196.53	180.68
1986	200.86	273.66	239.02	191.75	250.22	223.97	127.35	187.17	157.76	151.30	187.07	170.99
1987	207.02	267.33	238.64	200.37	253.13	228.81	129.07	180.57	155.23	155.41	184.73	171.27
1988	275.81	318.85	297.64	252.98	286.94	270.78	169.14	212.71	190.85	189.76	200.58	195.39
1989	269.48	328.77	300.30	240.71	293.23	268.07	162.59	216.67	189.85	179.93	202.41	192.03
1990	268.12	338.03	308.24	234.63	297.63	270.44	159.20	220.10	192.16	173.32	202.25	191.14
Annual Growth Rate (%)												
1956-66	-0.3	1.8	0.9	-0.6	1.4	0.6	-2.1	0.8	-0.5	-1.1	1.0	0.1
1967-77	3.1	3.3	3.2	2.5	2.7	2.6	2.0	1.7	1.9	1.9	1.8	1.8
1978-90	3.7	3.7	3.8	3.6	4.0	3.9	2.0	2.4	2.3	2.0	1.9	2.0
1956-90	2.9	3.6	3.4	2.5	3.3	3.0	1.4	2.3	1.9	1.6	2.1	1.9

for the index of aggregate production is:

$$lnYI_t = \sum_i 1/2 * (S_{i,\ t} + S_{i,\ t-1}) * \ln(Y_{i,\ t}/Y_{i,\ t-1}), \tag{1}$$

where $lnYI_t$ is the log of the production index at time t, $S_{i,\ t}$ and $S_{i,\ t-1}$ are output i's share in total production value at time t and t-1, respectively; and $Y_{i,t}$ and $Y_{i,\ t-1}$ are quantities of output i at time t and t-1, respectively. Farm prices are used to calculate the weights of each crop in the value of total production.

For all India, crop production grew at 3.4 percent per annum from 1956 to 1990. Prior to the green revolution, growth in crop production in Indian agriculture had been comparatively low, growing at an annual rate of only 0.9 percent. During the green revolution period, the widespread adoption of HYVs, together with increased use of fertilizer and irrigation, caused agricultural production to soar. Crop production grew at 3.2 percent per annum, a much higher growth rate than most other countries achieved during the same period. New technologies developed during the green revolution had an even greater impact in the post green revolution period. Production grew at 3.8 percent per annum during 1978-1990, 0.4 percentage points higher than that during the green revolution period. Production growth in irrigated areas has generally outperformed growth in rainfed areas; at 3.6 percent per annum it was 0.7 percent percentage point higher than growth in rainfed areas from 1956 to 1990.

Land productivity (measured as 1980 rupees per hectare of net cropped area) in rainfed areas was only 57 percent of that in irrigated areas in 1990. But back in 1956, it was 73 percent as large, indicating that the land productivity gap between rainfed and irrigated areas has grown larger in the past 35 years. Labor productivity (measured as 1980 rupees per year per person) was higher in rainfed areas than irrigated areas in 1956, but in 1990, labor productivity in rainfed areas was 17 percent lower than in irrigated areas.

To gain richer insights into the sources and efficiency of agricultural production growth, "total" rather than partial productivity indices were calculated. Total factor productivity is defined as aggregate output minus aggregated inputs. Again, a Tornqvist-Theil index is used to aggregate both inputs and outputs.

$$lnTFP_t = \sum_i 1/2 * (S_{i,\,t} + S_{i,\,t-1}) * \ln(Y_{i,\,t} / Y_{i,\,t-1}) - \sum_i 1/2 * (W_{i,\,t} + W_{i,\,t-1}) * \ln(X_{i,\,t} / X_{i,\,t-1}) \qquad (2)$$

Where $lnTFP_t$ is the log of the total factor productivity index, $W_{i,t}$ is the cost share of input i in total cost at time t, and $X_{i,t}$ is the quantity of input i at time t. Five inputs (labor, land, fertilizer, tractors and bullocks) are included. Labor input is measured as the total number of male workers employed in agriculture at the end of each year; land is measured as gross cropped area; fertilizer input is measured as total amount of nitrogen, phosphate, and potassium used; tractor input is measured as the number of four-wheel tractors; and bullock input is measured as the number of adult bullocks. Wages of agricultural labor are used as the price of labor; rental rates of tractors and bullocks are used for their respective prices; and the fertilizer price is calculated as a weighted average of the prices of nitrogen, phosphate, and potassium. The land price is measured as the residual of total revenue net of measured costs for labor, fertilizer, tractors, and bullocks[5].

Total factor productivity for India as a whole grew by 1.9 percent per annum from 1956 to 1990 (table 3). Prior to the green revolution, total factor productivity improved very

[5] This approach implicitly assumes that there is a perfect land rental market. If the residual is negative, the average shares of the zone where the district is located are used for aggregation.

little, growing at 0.1 percent per annum. During the green revolution period, growth in total factor productivity jumped to 1.8 percent per annum and then to 2 percent per annum thereafter. As with production growth, total factor productivity growth in irrigated areas has always outperformed rainfed areas. In the irrigated areas, total factor productivity grew at 2.1 percent per annum during 1956-90, while in the rainfed areas, it grew by 1.6 percent per annum.

5. RURAL POVERTY

The literature on poverty in rural India is extensive. Earlier studies have focused on time series analysis (Ahluwalia, 1978 and 1985; Ghose,1989; Gaiha, 1989; and Bell and Rich, 1994). The question that has been asked in these studies is to what extent changes in poverty can be explained by changes in agricultural income and prices. Few analyses have paid attention to difference in rural poverty among agroecological zones. One exception is Dreza and Srinivasan (1996) who analyzed regional patterns of poverty changes and the relationship between poverty decline and regional characteristics. Given that the incidence of poverty is often far from uniform within a particular state, the identification of intra-regional patterns can be important for development planning. Efforts to focus public investments on particularly deprived regions, for instance, require this type of information.

Table 4 shows the poverty incidence for different agroecological zones in 1972 and 1987. The underlying regional (agroecological zones) data reported in the table are taken from Dreze and Srinivasan (1995), and the rural poverty incidence (percentage of rural

Table 4 Poverty changes by regions

	Irrigated Areas	Rainfed Areas Total	Rainfed Areas High Potential	Rainfed Areas Low Potential
		1972		
Percentage of poor in total population (%)	42.9	52.7	55	49
Number of poor per thousand hectares crop land	1,875	1,707	2,466	1,166
Number of poor (millions)	86.8	90.1	44.2	43.7
		1987		
Percentage of poor in total population (%)	31	41	45.2	31.9
Number of poor per thousand hectares crop land	1,787	1,769	2,634	1,079
Number of poor (millions)	77.9	89.8	44.9	38.2
		Percent change between 1972 and 1987		
Percentage of Poor in Total Population (%)	-38.39	-28.54	-21.68	-53.61
Number of poor per thousand hectares crop land	-4.92	3.50	6.38	-8.06
Number of poor (millions)	-11.36	-0.36	1.51	-14.34

Sources: Authors' calculation based on data from Dreze and Srinivasan (1995).

population under the poverty line) was reaggregated into irrigated and rainfed, and low- and high-potential areas by the authors using rural population as weights. Rural poverty was estimated on the basis of consumer expenditure surveys carried out by the National Sample Survey Organization (NSSO). The poverty line is defined as Rs 15 per capita per month at 1960-61 prices[6].

[6] Nominal expenditures were deflated by state-specific price indices that take into account inter-state price differentials.

A noteworthy feature in these data is the high concentration of rural poor in high-potential rainfed areas, and the comparatively small reduction in poverty between 1972 and 1987 in these areas (by 22 percent), despite their relatively high agricultural potential. In contrast, poverty declined in low potential areas between 1972 and 1987. These areas accounted for 23 percent of the nation's total poor in 1987, down from 25 percent in 1972. The incidence of poverty also declined from 49 percent of the population to 32 percent over the same period.

The question as to whether poor regions grow faster than richer ones has received a good deal of attention in recent policy debates. The new growth model suggests that the difference in productivity and income between less-developed and developed regions will narrow over time (the so-called convergence or catch-up theory). But this is not the case in India. The poverty gap between rainfed and irrigated areas grew larger between 1972 and 1987. In 1972, the incidence of poverty was 43 percent in irrigated areas, and 53 percent in rainfed areas. In 1987, the poverty incidence had declined to 31 percent in irrigated areas, but to only 41 percent in rainfed areas; that is, poverty in irrigated areas fell by 38 percent, but only by 28 percent in rainfed areas. Therefore, the poor are increasingly concentrated in rainfed areas.

6. EFFECTS OF TECHNOLOGIES AND INFRASTRUCTURE ON PRODUCTIVITY AND RURAL POVERTY

In this section, we analyze how technologies and infrastructure have contributed to productivity growth and poverty reduction in both irrigated versus rainfed areas, and in high- versus low- potential areas within rainfed agriculture.

EFFECTS ON PRODUCTIVITY GROWTH

Conceptual Framework

The conceptual framework for an econometric analysis of the effects of public investments in technologies and rural infrastructure on productivity growth in irrigated and rainfed areas, and in high- and low-potential areas are illustrated in a system of equations (3) to (5).

$$TFP_{i,t}=f(HYV_{i,t},\ PIRRI_{i,t},\ LITE_{i,t},\ ROAD_{i,t},\ ATT_{i,t},\ T), \tag{3}$$

$$PIRRI_{i,t_{i,t}}=f(FPRICE_{i,t-1},TPRICE_{i,t-1},WAGE_{i,t-1},ROADS_{i,t-1},LITE_{i,t-1},ATT_{i,t}), \tag{4}$$

$$HYV_{i,t}=f(FPRICE_{i,t-1},TPRICE_{i,t-1},WAGE_{i,t-1},ROADS_{i,t-1},LITE_{i,t-1},PIRRI_{t-1},ATT_{i,t}). \tag{5}$$

The dependent variable is total factor productivity growth ($TFP_{i,t}$), while explanatory variables are the percentage of HYVs in total cropped area ($HYV_{i,t}$), the percentage of the total cropped area that is irrigated ($PIRRI_{i,t}$), the literacy rate of the rural population ($LITE_{i,t}$), road density ($ROAD_{i,t}$), and a lagged terms of trade variable ($ATT_{i,t}$) which is measured as the previous five year average of agricultural prices divided by a relevant GNP deflator[7]. The

[7]In traditional production theory, only inputs are included in the production function. Any changes in prices of both inputs and outputs do not affect output directly, but indirectly

time trend variable, T, and spatial (district) intercept dummies were also added in order to reduce the potential biases caused by quality differences of inputs among regions and changes over time, and the omission of variables that are not included in the function.

Our list of technology and infrastructure variables is incomplete, but these are key ones for which we have district level data. Due to the endogeneity of HYVs and irrigation variables in the TFP function, a simultaneous equation system was estimated[8]. Therefore, in addition to the TFP function, irrigation and the adoption of high yielding varieties are also modeled as endogenous variables. These two variables are mainly determined by lagged factor and output prices *(FPRICE* (fertilizer price), *TPRICE* (tractor price), and *ATT* (five-year lagged terms of trade)), and other infrastructure variables like rural education, *LITE*, and road density, *ROADS*.

Empirical Results

Time series (35 years: 1956 to 1990), and cross-district (243) data were used for the regression. Mountain districts were not included due to data unavailability. The total number of observations is 8,505. Because we are interested in differences between the impacts of

through input changes. Therefore, if both input and price changes are included in the production function, there may be a double counting problem among the explanatory variables. Here we include lagged (average of the last five years) relative price changes in the productivity function. We argue that in the long run, the relative price changes will induce the research system to develop new technologies and to induce farmers to use these technologies, therefore, the production frontier will move upward (Hayami and Ruttan, 1985).

[8] If governments allocate public investments (PIRRI and HYV) based on agroclimatic potential of the districts in equations (3), then these variables are correlated with the error term. In that case, we can estimate (3) consistently only if we instrument for the public investment variables that are correlated with the error term.

investments on rainfed and irrigated areas and between high- and low-potential areas, a variable coefficients model was estimated. This is equivalent to adding slope dummies for each variable. In this case, the coefficients on each variable may vary between irrigated and rainfed areas, and between high- and low-potential areas.

Using a full-information maximum likelihood method, the system was estimated for three periods, 1956-64, roughly corresponding to the pre-green revolution period; 1967-77, representing the green revolution period; and 1978-90, representing the post-green revolution period[9]. Both linear and double-log functional forms were estimated, but the linear form gave the better fit and had more statistically significant coefficients[10]. Only the results of the linear form are presented here.

First, we estimated the system to compare the effects on productivity between irrigated and rainfed areas. The results are presented in table 5. Because of space limitations, only the TFP function results are presented in the table. During the green revolution period (1967-77), the use of HYVs was a significant factor in contributing to total factor productivity growth. The marginal effect in irrigated areas was larger than that in rainfed areas. After the green revolution, the adoption of HYVs had no significant impact on total factor productivity in irrigated areas, but they still had a positive and statistically significant impact in rainfed areas. As Rosegrant and Evenson (1995) pointed out, this pattern may be due to the fact that during the post-green revolution period, the impact of agricultural research has been mainly

[9] The years of 1965 and 1966 were dropped from the estimation because of severe droughts in those two years.

[10] This may be due to the fact that most of the explanatory variables (PIRRI, HYV, and LITE) are measured in percentages.

Table 5 Estimates of total factor productivity functions, rainfed vs irrigated areas

Variable	Type	1956-64		1967-77		1978-90	
		Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
HYV	Irrigated			0.759	6.170	-0.095	-1.622
	Rainfed			0.290	2.510	0.054	2.550
IRRI	Irrigated	0.433	3.610	0.059	0.422	0.582	5.480
	Rainfed	1.719	6.040	2.010	6.230	2.813	8.920
ROAD	Irrigated	0.012	9.760	0.011	8.670	0.010	16.760
	Rainfed	0.015	9.750	0.015	2.780	0.008	3.030
LITE	Irrigated	-2.319	-1.650	-2.401	-0.499	-1.614	-1.723
	Rainfed	-1.583	-0.310	-1.694	-1.910	-0.355	-1.298
ATT	Irrigated	0.111	1.360	0.230	2.780	0.295	2.428
	Rainfed	0.219	1.300	0.229	2.770	0.524	1.433
R^2		0.703		0.839		0.876	

Notes: Coefficients on district dummies are not reported. The full system of equations (3)-(5) was estimated, but only the estimates of the TFP function are reported here.

through replacement of older generations of HYVs by newer generations with improved traits, rather than through direct expansion of HYVs to new areas, particularly in irrigated areas.

Irrigation has been an important factor in promoting productivity growth in both irrigated and rainfed areas since 1956. The coefficients of the irrigation variable in the rainfed areas are consistently larger than those in irrigated areas, and they have been increasing over time. This implies that increased investment in irrigation in rainfed areas will generate even bigger productivity effects in the future.

Additional roads have also been an important factor for productivity growth in both rainfed and irrigated areas. While the marginal effect of roads has changed little over time for irrigated areas, it still remains statistically significant. However, it has been declining in rainfed areas. This could be due to several factors. One of them is a measurement problem. The quality of roads in rainfed and irrigated areas may be quite different. Without adjusting for quality, the estimated coefficients are likely to be biased. The second reason could be that since road density in rainfed areas is now higher than in irrigated areas, the marginal returns are necessarily lower.

Improvements in literacy have had little effect on total factor productivity in both rainfed and irrigated areas. In fact, all the literacy coefficients have negative signs, though all except one are statistically insignificant. This is consistent with Hayami and Ruttan's (1985) findings for other developing countries.

Changes in the terms of trade have had a positive, though not always statistically significant impact on agricultural productivity in both rainfed and irrigated areas, indicating that improvements in the terms of trade can increase production and productivity growth in Indian agriculture.

We further divide rainfed areas into high- and low-potential areas. The results are presented in table 6. The marginal effects of HYVs on productivity growth are positive in both low- and high-potential areas, but are much higher in the low-potential areas. Both are declining over time. Irrigation has also had a positive impact, which has been greater in the low-potential areas than in the high-potential areas. Road density has had a positive and statistically significant impact, but which has been highest in the high-potential areas. Literacy gains have had little impact on agricultural productivity in high- potential areas, but a positive and significant impact in low-potential areas during the post-green revolution period. The changes in the terms of trade have been significant in determining total factor productivity growth in both low- and high-potential areas, but less so in the post-green revolution era.

EFFECTS ON RURAL POVERTY

Conceptual Framework

Technologies and infrastructure affect poverty directly and indirectly as specified in equations (6) to (9).

$$P_{t,i}=f(TFP_{i,t},\ WAGE_{i,t},\ TT_{i,t},\ LITE_{i,t},\ ROAD_{i,t},\ T) \tag{6}$$

$$TFP_{i,t}=f(HYV_{i,t}\ PIRRI_{i,t},\ LITE_{i,t},\ ROAD_{i,t}\ ATT_{i,t}) \tag{7}$$

$$WAGE_{i,t}=f(TFP_{i,t-1}) \tag{8}$$

$$TT_{i,t}=f(TFP_{i,t},\ CPI_{i,t-1}) \tag{9}$$

Table 6 Estimates of total factor productivity functions, high- vs low-potential rainfed areas

Variable	Type	1956-64 Coefficient	1956-64 t-value	1967-77 Coefficient	1967-77 t-value	1978-90 Coefficient	1978-90 t-value
HYV	High Potential			0.055	0.649	0.046	1.339
	Low Potential			1.175	4.604	0.147	1.627
IRRI	High Potential	0.098	0.921	0.082	0.268	0.547	2.089
	Low Potential	1.166	1.123	0.355	3.885	1.207	1.911
ROAD	High Potential	0.032	6.042	0.016	3.613	0.014	4.197
	Low Potential	0.004	3.791	0.005	2.355	0.001	3.889
LITE	High Potential	-0.816	-2.912	-0.389	-1.224	-0.324	-1.263
	Low Potential	0.334	1.126	-1.938	-1.617	2.499	4.617
ATT	High Potential	-0.415	3.225	0.513	3.125	0.266	1.642
	Low Potential	0.245	3.852	0.344	3.490	0.010	1.089
R^2		0.712		0.866		0.892	

Notes: Coefficients on district dummies are not reported. The full system of equations (3)-(5) was estimated, but only the estimates of the TFP function are reported here.

The indirect effects arise mainly from improved agricultural productivity, while direct effects arise from improved off-farm income earning opportunities. For example, improved education may help farmers find a better job in the non-agriculture sector, thereby increasing their incomes and reducing poverty. Relative price changes (agricultural vs non-agricultural prices) in the short run, usually measured as the terms of trade in the current year, also affect rural poverty. It has been argued that in the short run, increases in agricultural prices may hurt the poor because they are usually net buyers of grains. But in the long run, increased agricultural prices (measured as changes in ATT in equation (7)) will stimulate government and farmers' investment in technology to increase supply, thereby reducing agricultural prices and increasing wages.

We model the poverty determination function as a function of productivity growth, public investments, wages and the terms of trade in order to capture both direct and indirect effects. Because productivity, agricultural wages and agricultural prices are all endogenous in this framework, we model poverty determination as a system of several equations.

The poverty variable $P_{i,t}$ is defined as the percentage of the rural population below the poverty line as defined earlier in this paper. The wage variable $WAGE_{i,t}$ is defined as daily wage for male agricultural labor deflated by consumer price index for agricultural labor, while the terms of trade $TT_{i,t}$ is measured as the agricultural GDP deflator divided by non-agricultural GDP deflators in the current year. The *CPI* is the consumer price index for agricultural laborers. All other variables are defined earlier in the paper.

Equation (6) models the relationships between poverty and agricultural productivity while controlling for other socioeconomic factors. Literacy rate and road density are included in the function to capture the direct impact of these public investment variables on poverty reduction. The *HYVs* and *PIRRI* variables are not included in the poverty function, mainly because these two variables only affect poverty indirectly through improved productivity[11], and hence are captured in equation (7). Equation (8) is a wage determination function. When productivity rises, it increases the demand for labor, thereby increasing wages. Equation (9) is specified to model the determination of the terms of trade. When productivity increases, agricultural prices may decline. As a result, the terms of trade may change. The consumer price index (for agricultural laborers) also affects the terms of trade.

Empirical Results

Data for thirty-eight agroecological zones and two years (1972 and 1987) are used in the estimation (with 96 total observations). Because of space limitations, only the results of the poverty determination function are reported. Four different specifications for the poverty determination function were estimated in order to test the robustness of the system. Table 7 shows the results based on a variable coefficients model for both irrigated and rainfed areas. Total factor productivity growth in rainfed areas has helped reduce poverty, but not in irrigated areas. This implies that there may be tradeoffs between productivity growth and poverty reduction in irrigated areas. Increased public investments promote agricultural productivity, but do not necessarily reduce poverty. Increased wages reduce poverty in both rainfed and irrigated areas, but the effect in irrigated areas seems greater than that in rainfed areas. Additional roads generally have little *direct* impact on poverty reduction in spite of

[11] When these two variables are included in the poverty function, they are not statistically significant.

Table 7 Estimates of poverty determination function: irrigated vs rainfed areas

		Model 1		Model 2		Model 3		Model 4	
Variable	Type	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
TFP	Irrigated	0.069	3.035	0.030	1.101				
	Rainfed	-0.069	-6.082	-0.065	-3.471				
WAGES	Irrigated	-2.723	-12.103	-2.711	-9.516			-1.908	-5.823
	Rainfed	-1.958	-3.181	-1.451	-2.612			-1.918	-5.853
TT	Irrigated	-0.164	-2.342	-0.152	-2.173			-0.104	-1.535
	Rainfed	0.106	3.818	0.086	3.359			-0.014	1.303
ROADS	Irrigated			0.001	1.613	0.003	8.457	0.002	4.376
	Rainfed			-0.000	-1.799	0.000	-6.567	-0.000	-4.288
LITE	Irrigated			-0.053	-0.241	-0.135	-0.667	-0.017	0.077
	Rainfed			-0.185	-0.793	-0.404	-1.258	-0.300	-1.921
HYV	Irrigated					-0.530	-6.389	-0.389	-4.791
	Rainfed					-0.119	-4.513	-0.129	-2.901
IRRI	Irrigated					0.010	0.111	0.050	0.601
	Rainfed					-0.491	-4.642	-0.469	-5.224
R2		0.524		0.544		0.462		0.564	

Notes: The full system of equations (6)-(9) was estimated simultaneously, but only the estimates of the poverty equations are reported here.

their significant impact on productivity as shown earlier[12]. Improvements in literacy reduce poverty in both rainfed and irrigated areas, though the effects in rainfed areas are much greater than in irrigated areas. At the same time improved literacy has almost no impact on productivity growth, as shown in tables 5 and 6. When the TFP variable is replaced by HYV, PIRRI and ATT in the poverty determination function, and equation (7) is dropped from the system (i.e., combine equations (6) with (7)), the adoption of HYVs and increased rate of irrigation reduce poverty in both rainfed and irrigated areas, confirming that HYVs and irrigation affect poverty mainly through improved productivity.

Again, we further disaggregate rainfed areas into high- and low-potential areas. The results are presented in table 8. Growth in TFP has contributed to reductions in poverty in both high- and low-potential areas, and the difference of these impacts is small between low- and high-potential areas. Increased wages in both low- and high-potential areas have helped reduce poverty, and there is no noticeable difference between the two. Additional roads have generally had little *direct* impact on poverty in both high- and low-potential areas. Improved literacy has been the most effective way of alleviating poverty in low potential areas. The use of HYVs and irrigation has also helped reduce poverty in both low- and high-potential areas

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[12] The direct and indirect impacts of public investment variables on poverty can be calculated using the chain rule through equations (6) and (7), i.e.,

$$\frac{dP}{dH} = \frac{\partial P}{\partial H} + \frac{\partial P}{\partial TFP}\frac{\partial TFP}{\partial H}$$

where H is a vector of public investment variables, P is the percentage of poverty, and TFP is total factor productivity. The first term of the above equation measures direct impact of public investment, and can be calculated from equation (6), while the second term captures the indirect impact through improved productivity in equation (7).

Table 8 Estimates of poverty determination function, high- vs low-potential rainfed areas

		Model 1		Model 2		Model 3		Model 4	
Variable	Type	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
TFP	High Potential	-0.061	-7.602	-0.065	-7.541				
	Low Potential	-0.056	-3.339	-0.076	-7.743				
WAGES	High Potential	-1.670	-4.806	-1.947	-5.401	-2.485	-7.561		
	Low Potential	-1.583	-2.643	-1.508	-3.873	-1.408	-3.737		
TT	High Potential	-0.083	-2.085	-0.083	-2.073	-0.298	-7.691		
	Low Potential	0.171	5.637	0.116	4.255	0.118	9.036		
ROADS	High Potential			0.001	0.716	-0.004	-1.822	0.005	2.338
	Low Potential			0.000	0.447	0.000	1.828	0.001	2.085
LITE	High Potential			0.200	0.997	0.106	0.568	-1.008	-5.988
	Low Potential			-0.435	-2.863	-0.102	-1.011	-0.231	-5.988
HYV	High Potential					0.056	1.378	0.164	2.054
	Low Potential					-0.153	-2.616	-0.262	-4.684
IRRI	High Potential					-0.694	-7.191	-0.559	-4.985
	Low Potential					-0.468	-6.941	-0.435	-2.324
R^2		0.573		0.665		0.677		0.467	

Notes: The full system of equations (6)-(9) was estimated simultaneously, but only the estimates of the poverty equations are reported here.

through their agricultural productivity effects. Changes in the terms of trade have negative short-run impacts on poverty reduction in low potential areas. When agricultural prices increase, the poor, who are mostly net buyers of food grains, experience increases in their living costs. This is consistent with Misra and Hazell's (1996) findings, and indicates that price and market reforms in developing countries may hurt the poor in the short run if not accompanied by appropriate safety net programs.

7. CONCLUSIONS

This study has found that improved technologies and rural infrastructure have contributed to both productivity growth and reductions in rural poverty. But these effects have large regional variations. In the past, the government has devoted more resources to irrigated areas (except roads), and this has led to significant production and productivity growth in these areas. However, as investments in irrigated areas continue to increase, their marginal returns have begun to decline, and it is now rainfed areas not irrigated areas where the marginal returns from government investments in technologies and infrastructures are largest.

Disaggregation of rainfed areas into high- and low-potential areas showed that the marginal productivity effects of increases in HYVs, irrigation and literacy are greater in low- than in high-potential areas. But the returns from roads are smaller in low- than in high-potential areas.

Poverty reduction in rural India has also shown considerable regional variation. It is the rainfed areas where the rural poor are most concentrated, and poverty reduction in these areas has been relatively small. Government investments can reduce poverty both directly and indirectly. The indirect effects mainly arise from improved agricultural productivity; the so-called trickle down hypothesis. We found that growth in total factor productivity has no impact on poverty reduction in irrigated areas, but large poverty reducing effects in rainfed areas (in both high- and low-potential areas). In contrast, improved literacy has been one of the most effective ways to reduce poverty in both irrigated and rainfed areas. Therefore, in rainfed areas, increased government investments not only improve productivity, but also reduce rural poverty.

The findings of this study have important policy implications for future Indian government investments. If the government's priority is to reduce the number of poor people, more investments should be allocated to rainfed areas. These investments also seem to be desirable in terms of increasing agricultural growth, offering a win-win situation in achieving growth and poverty alleviation goals. In the more favorable areas, more investments are needed to improve the current HYVs, rather than to expand the total area planted to HYVs. Additional investments in rural education will also be an effective means to reduce poverty particularly in the more favorable areas, as improved literacy will help farmers increase off-farm employment opportunities.

While this study has provided an initial framework for thinking about more efficient allocation of public investments in Indian agriculture, additional research is needed to analyze both the benefits (or social welfare) and costs of different government investments in different agroecological and geopolitical regions. This will provide more meaningful information for the government in setting its priorities for future investment portfolios designed to achieve further productivity growth and to reduce rural poverty. Further research is also needed to disaggregate the results by geographic regions, and to better define low- and high-potential areas in order to provide more accurate estimates of potential impacts of investments on productivity growth and poverty alleviation in different types of agriculture.

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